Passive Autonomous Acoustic Monitoring of Marine Mammals: System Development Using Seaglider™ FY2012 Annual Report

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LONG-TERM GOALS

A group within the Applied Physics Laboratory of the University of Washington (APL-UW) dedicated to the use of autonomous underwater vehicles in support of Navy missions executed this program. The group generally uses the Seaglider™, developed at APL-UW, and develops or adapts instruments and glider behavior to support specific mission requirements. This group is informally called the Applied Seaglider Group, whose acronym (ASG) is also used to describe the Seaglider itself.

This report describes ongoing efforts as part of the ONR Passive Autonomous Acoustic Monitoring (PAAM) program. The original long-term goals of the PAAM program were as follows.

- Perform persistent and autonomous passive acoustic monitoring of a 500-1000 square nautical mile Navy exercise area for presence of marine mammals.
- Monitor for three weeks prior to, three weeks during, and three weeks after a typical exercise.
- Detect, classify and localize (DCL) vocalizing marine mammals.
- Provide actionable information in a timely manner to the officer in tactical command to support marine mammal mitigation efforts.

Over the past several years, the long-term goals of the ONR PAAM program have changed to concentrate on the DCL mission in support of monitoring of marine mammals, particularly in Navy operating areas. In particular, a primary goal is to provide a persistent (many months) marine mammal monitoring capability in Navy operating areas that are remote or difficult to monitor by traditional means. These include the Pacific Northwest, Gulf of Alaska, and Mariana Islands operating areas.

OBJECTIVES

With previous ONR funding (N00014-08-1-0309), we have enhanced the passive acoustic detection, recording, and on-board processing capabilities of the Applied Seaglider (ASG), with particular

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attention to the automated detection of beaked whale echolocation clicks. In particular, we have designed and built a new passive acoustic detection and recording system for ASG, and tested this system in the field several times.

The objectives of this program are to successfully demonstrate the single-channel acoustic recording system in a long-duration mission in a relevant Navy operating area, enhance the on-board detection and classification software, and to investigate the utility of multiple hydrophones.

This is the last year of this program, and our main objective was to do a long deployment in the Seaglider/PAAM baseline single-hydrophone configuration. The baseline version of the current Seaglider/PAAM system had only been run on short missions (one week or less). A long open-ocean mission presented the best opportunity to exercise the system, especially the data management aspects critical to successful recording missions.

APPROACH

The program originally was focused on automated detection, classification, and recording of beaked whale vocalizations. Over the life of the PAAM program, however, the Navy's needs shifted from real-time notification for mitigation to long-term monitoring to support permit applications and meet environmental compliance requirements.

Our approach was as follows.

- Treat the single-hydrophone PAAM electronics system as deployed at AUTEC in June, 2010, and at SCORE in January, 2011, as a baseline.
- Execute long-duration (greater than one month) missions.
- Investigate installation of multiple hydrophones and suitable re-configuration of the electronics.
- Continue to collaborate with Drs. David Mellinger and Holger Klinck at Oregon State University (OSU) on improved detection and classification algorithms and on the scientific utility of multiple hydrophone installations.

Key participants at APL-UW, in addition to the Principal Investigators listed above, were Geoff Shilling (software engineer), Sean McPeak (electrical engineer), and Mike Carpenter (electrical engineer). Drs. David Mellinger and Holger Klinck at OSU provided detection and classification algorithms and data analysis.

WORK COMPLETED

Our work in FY2012 was concentrated on executing a long-duration (multi-month) deployment. The preparation included software engineering to implement lessons learned from our earlier short deployments, and try to anticipate problems on a longer deployment.

One significant deployment was completed during FY2012. Seagliders sg178 and sg179 were launched on 11JUN2012 off the F/V TOMMYCOD approximately 30 nautical miles due west of Westport WA. The plan was to run sg178 in offshore-onshore transects with one end at J. Hildebrand's HARP mooring at approximately 47° 30'N, 125° 21'W. Seaglider sg179 was to survey

along the Washington coast just offshore of the 1000m isobath, with significant time spent surveying atop the HARP mooring mentioned above.

Seagliders 178 and 179 were recovered on 12JUL2012, from the F/V TOMMYCOD about 25 nautical miles due west of Westport WA, after completing 149 and 155 dives, respectively. Surfacing positions for each Seaglider are shown in Figure 1.

RESULTS

Results from our only field test in FY2012 were disappointing. Seagliders sg178 and sg179 experienced significant problems with their PAAM systems during the mission, which resulted in their recovery after only one month of operations. Both Seagliders worked well as underwater vehicles. They were able to navigate successfully on their prescribed tracks. The vehicles themselves did not experience any problems.

Unfortunately, the data return was meager, as shown in Table 1.

Table 1. Summary of Seaglider/PAAM system performance on Washington Coast mission, June-July 2012.

Seaglider	Dives	PAAM On	Data Recorded	Usable Data	Comment
178	149	17	13	1	Noise
179	155	92	61	61	Data management problems

Seaglider 178 developed a serious noise contamination issue starting at about 55m depth on its second dive. This rendered the acoustic time series essentially unusable for the remainder of the mission. After several days of unsuccessful attempts to remotely debug and solve this problem, the PAAM system on sg178 was secured for the duration of the mission. We believe this noise contamination was due to a small seawater leak into one of the underwater connectors between the hydrophone and the aft endcap of sg178's pressure hull. The leak may have been at the one of the connectors or somewhere along the cable between the hydrophone and the pressure hull. We have not seen this before on the PAAM system, but have had at least one similar failure of a Seaglider GPS/Iridium antenna cable on another project. Seaglider 178 passed all its pre-launch self-tests, and did a successful initial trim dive to 45m. The failure at 55m on the second dive is suggestive of a pressure-induced leak of seawater into a connector (or wicking of water to the connector through a leak in the cable). We do not think this is a systematic problem. We will replace the hydrophone assembly, along with its cables and connectors, and repeatedly pressure cycle them before sg178's next mission.

Seaglider 179 experienced problems with its data management system. The PAAM electronics are controlled by a single-board ARM-9 computer running Linux. The PAAM system configuration was to run with one microSD card as the system disk, and another microSD card as the primary data disk. Two USB sticks were cabled to the computer, under system software control with respect to mounting. Our approach was to record acoustic time series initially to the primary data disk, and as time and computing cycles allowed, move the time series data to one of the USB sticks. This would free storage space on the primary data disk as the mission proceeded.

About one week into the mission, the system began to have trouble mounting the USB sticks. It often became stuck in a cycle of repeatedly trying to check the integrity of the file system on the USB stick. That operation would often take longer than the time alloted to the movement of data. This effectively blocked use of that USB stick until the pilot held the Seaglider at the surface and manually managed the process. There were dives where the PAAM system was powered on, but spent its entire time trying to check the integrity of its various file systems, and was unable to record any data. Eventually, the problem effectively disabled the PAAM system on sg179. We did obtain 61 dives worth of good quality recordings. Those recordings are now being analyzed by the Oregon State University team led by Drs. Dave Mellinger and Holger Klinck, but results are not yet available.

We assume the same data management problem would have struck sg178 if we had not secured its PAAM system due to the noise contamination.

We believe that our storage architecture is a good one, and that there are configuration changes and a small amount of protective system-level software that will prevent this problem from recurring. We need a robust, reliable data management system capable of handling all the recordings from a three-month mission. We plan to perform the preventative software work before the end of the program, but sufficient funds do not exist to support another lengthy test. We look forward to that opportunity with other funding in the future.

IMPACT/APPLICATIONS

The Seaglider/PAAM detection and recording system has achieved an initial operational capability with a single omni-directional hydrophone. Although several problems appeared in our long-duration mission, we think they are surmountable without major hardware or software.

Once the storage management issues are addressed and tested locally, we feel we are ready to undertake a three-month demonstration mission in one of the Navy operating areas mentioned above.

We are also ready to build and install the PAAM system into Seagliders for researchers outside of our APL-UW development group. Seagliders themselves would have to be supplied, of course, from an investigator's existing research stock, or through purchase from iRobot, Inc., the UW-licensed manufacturer. We will provide quotes on request from interested investigators. Either co-PI listed at the top of this report can respond to such requests.

We are also ready to build, integrate, and install the PAAM system into other oceanographic or sampling systems. In this case, there will be non-recurring hardware and software engineering charges in addition to the fabrication and installation costs.

It is important to note that we treat the Seaglider/PAAM system as a U.S. export controlled item, both under the Department of State's ITAR and the Department of Commerce's EAR programs. We will only provide the PAAM system to verifiable U.S. persons, in situations where no export license is required. It will then be the responsibility of the purchasing investigator to remain in compliance with all applicable export control regulations.

RELATED PROJECTS

The primary related project was the previous ONR-funded PAAM work, under N00014-08-1-0309, as mentioned above. That project performed the initial PAAM development, and carried out four major sea trials, including short deployments at both AUTEC and SCORE. It ended on 30APR2011.
There are many related projects to use passive acoustics on autonomous platforms to detect, classify, and monitor marine mammals; some are funded as part of ONR's broader PAAM program, some are supported elsewhere.

Dr. David Mellinger at OSU is directly funded by ONR under the PAAM program to provide beaked whale detection and classification algorithms. Dr. Mellinger and his colleague Dr. Holger Klinck also provide consultation on the placement and use of the multiple hydrophones on the Seaglider™/PAAM system.

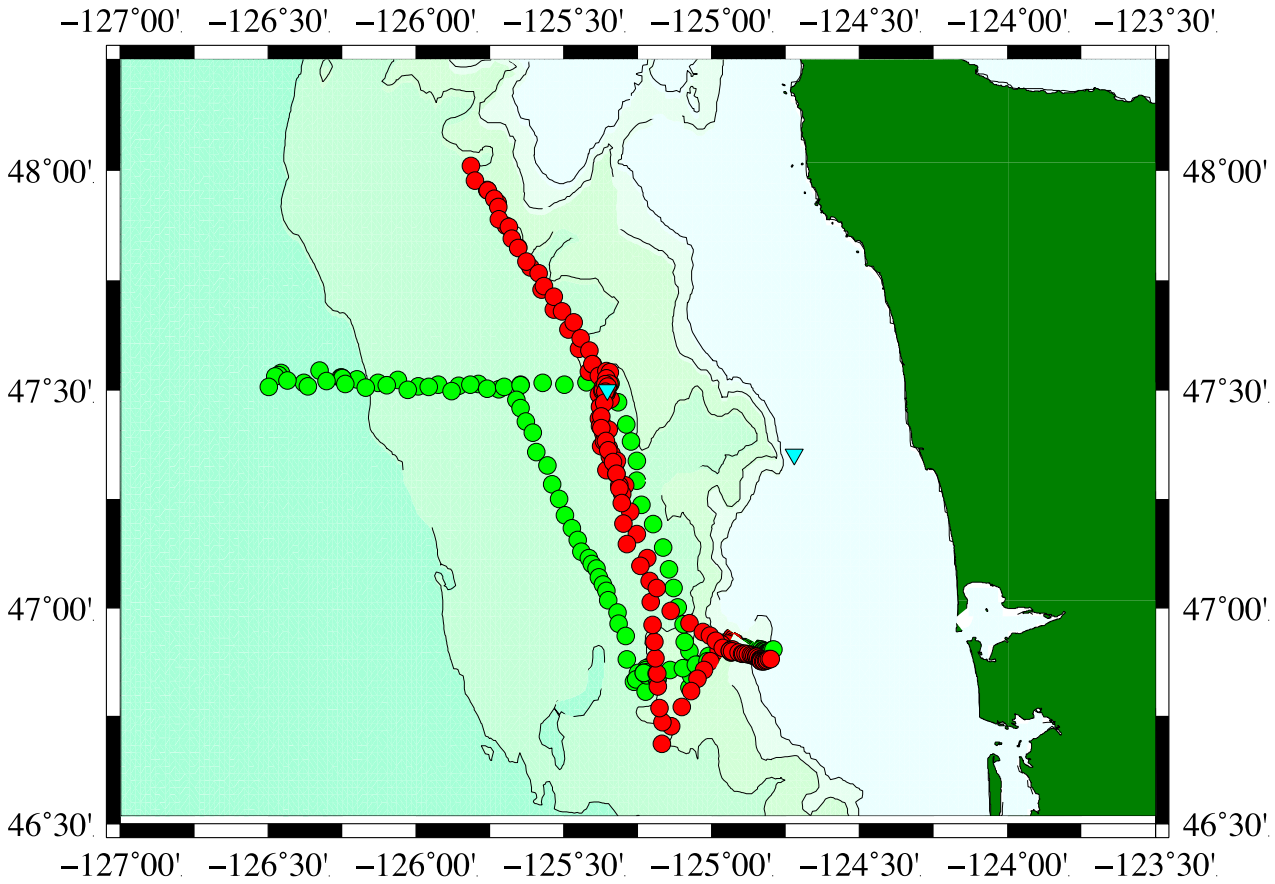

Figure 1. Surfacing positions of Seagliders S/N178 (green) and S/N179 (red) 11JUN-12JUL2012. HARP mooring locations (Wiggins, private communication) are indicated by inverted cyan triangles. The one-month mission demonstrated the Seagliders' ability to perform transects and to survey along designated isobaths.